Electric Utility NOx Reduction Options

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Current Requirements

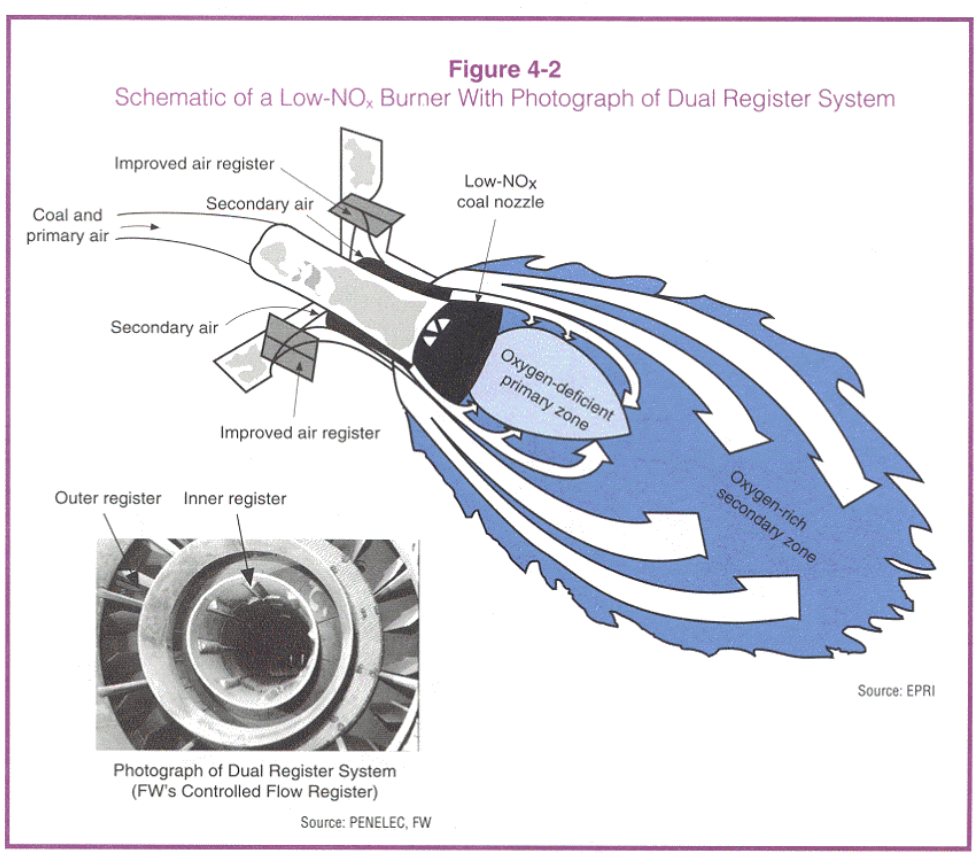
- All utility boilers subject to Title IV
  - Limits vary by boiler type from 0.40 to 0.86 lbs/MMBtu
  - Averaging of common ownership units allowed
- Ozone SIP call
  - Limits based on 0.15 lbs/MMBtu with state specific growth factor
  - Cap and trade system allows unit specific response to vary from overcontrol to no control
- Boiler specific limits
  - Non-attainment SIPS
  - NSPS
  - BACT

Options for Additional Reductions

- Virtually all utility boilers now have some level of NOx control
- Many (over 150) of the largest utility boilers will be equipped with highest level NOx control technology (Selective Catalytic Reduction)
- Current options
  - Combustion modifications
  - Post combustion control equipment

Combustion Modifications

- Combustion Modifications
  - Combustion Optimization
  - Burner Component Modifications
  - Overfire Air
  - Low NOx Burners
  - Fuel Lean Gas Reburn
  - Gas Reburn



Recent Results from Combustion Modifications

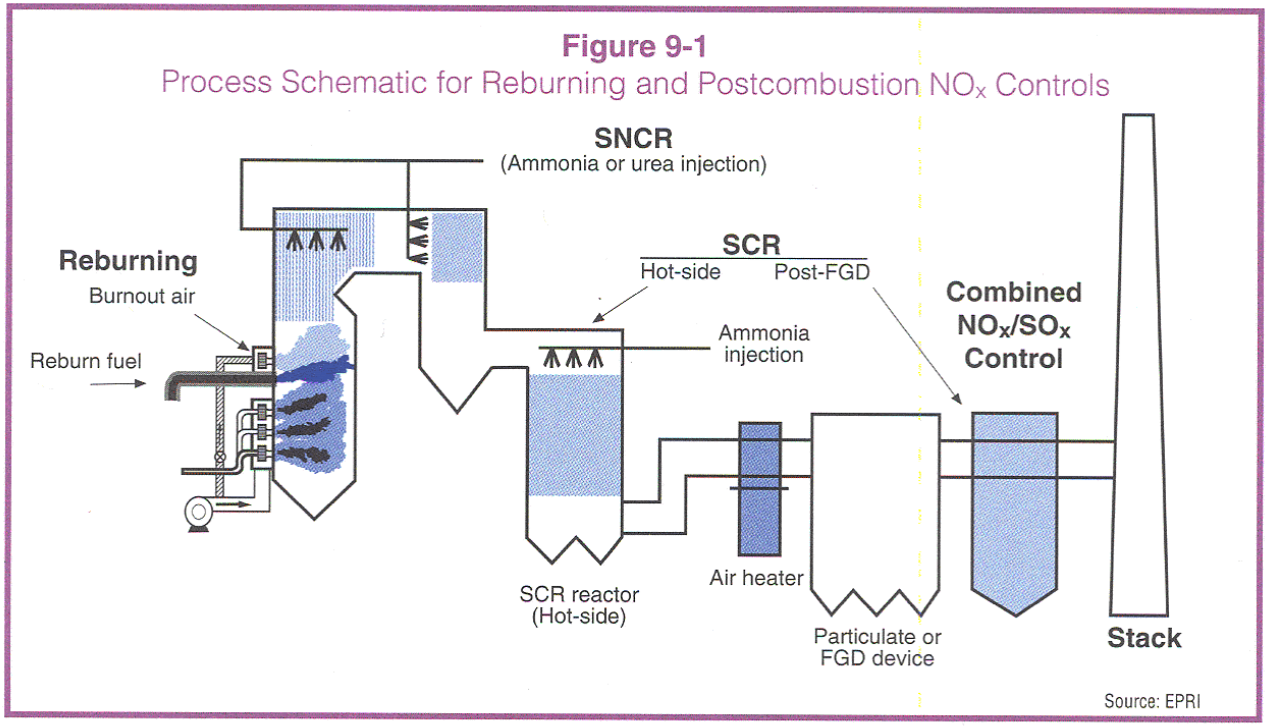
Unit	Coal	OFA System	NOx (lb/MBtu)	Emissions Reference
Ameren Rush Island 2	PRB	LNCFS III	0.100	3Q 2002 CEMS
AEP Pirkey 1	Low S Texas Lignite	ABT	0.170	3Q 2002 CEMS
Duke Energy Marshall 4	Low S Eastern Bit	CCOFA/SOFA + LOFIR	0.255	3Q 2002 CEMS
Dynegy Vermilion 2	Med S Illinois	NEI/ICL	0.305[2]	2Q 2001 CEMS

Post Combustion Control Options

- May be used in combination with combustion modifications
- Commercial
  - Selective Catalytic Reduction (SCR)
  - Non-selective Catalytic Reduction (SNCR)
- Near Commercial
  - Selective Autocatalytic Reduction (NOxStar)
  - ECO-tube
- Developmental
  - Many multi-pollutant; not expected to be available in time for 8-hr ozone SIPs.

SNCR Technologies

- Conventional SNCR
- SNCR Trim
- AEFLGR™
- RotaMix™
- SNCR Hybri
  Approaches



SNCR Technologies Summary

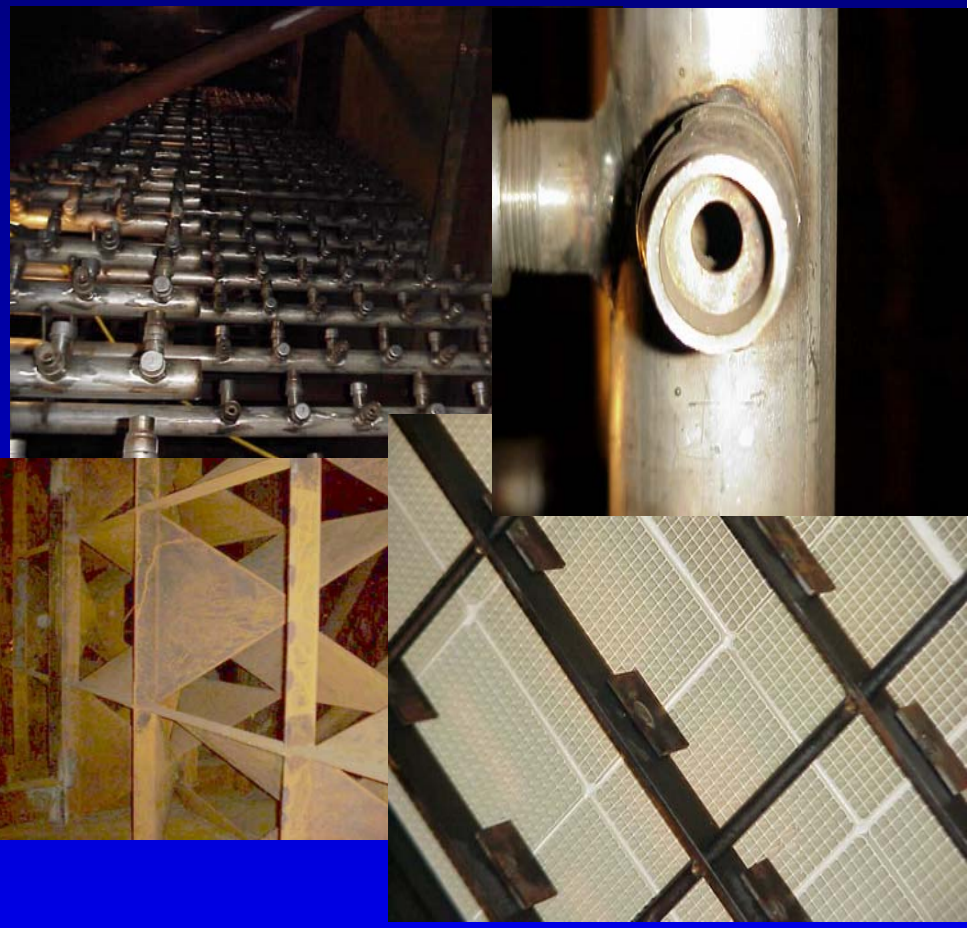
- SNCR processes tend to be site specific applications
  - Range of NOx reduction performance and cost effectiveness
- Increased application in utility industry seen as cost of NOx allowances increase
  - SNCR technologies typically achieve between 25% - 40% NOx reductions
  - Cost effectiveness range between $1,000 - $4,000 per ton NOx removed

SNCR Technologies Performance & Cost

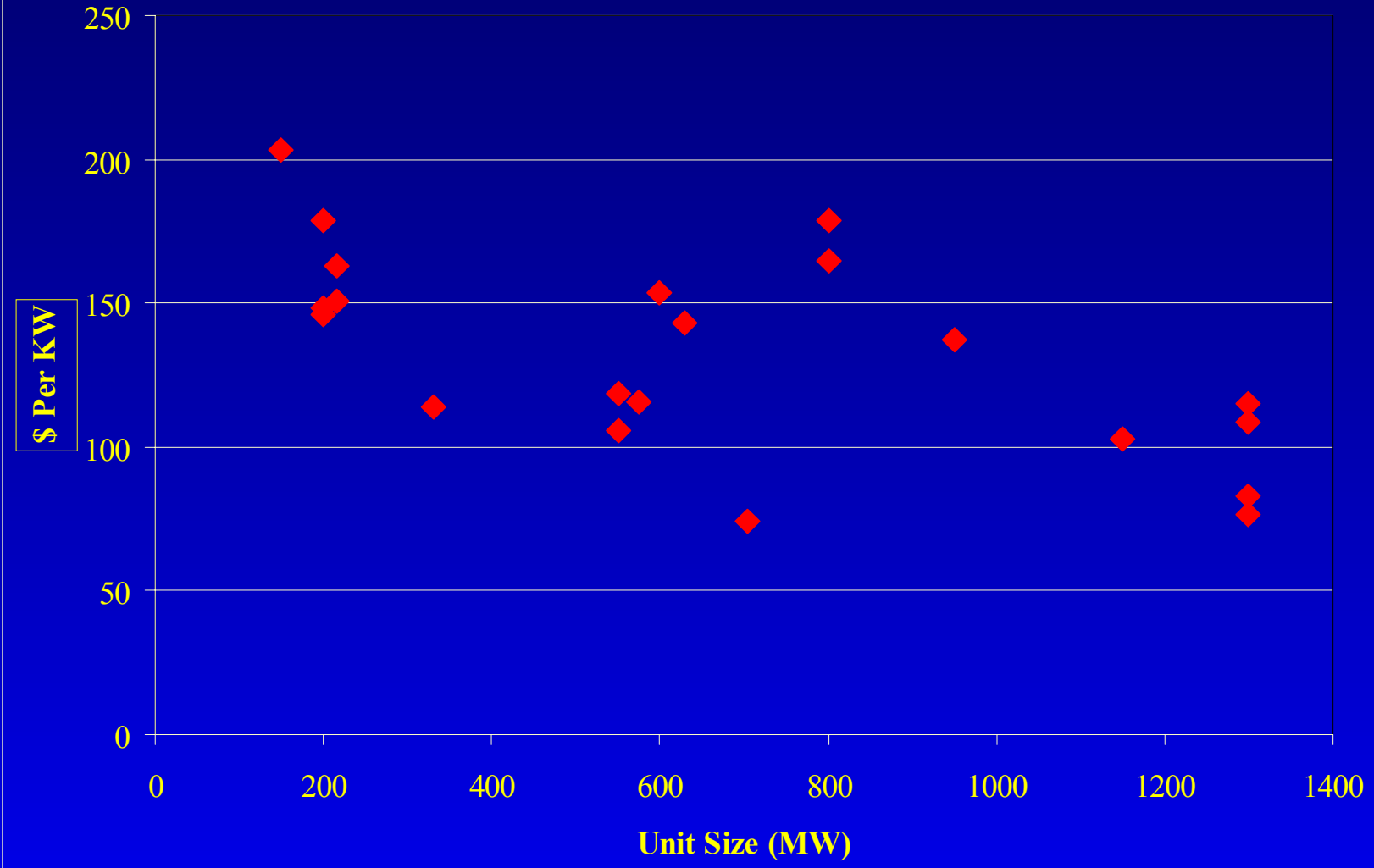
Technology	ΔNO_x	NH_3 Slip (ppmv)	Capital Cost ($/kW)	Cost Effectiveness ($/ton)
SNCR Trim	25% - 35%	5 – 12	4 – 8	$1,000 - $2,500
SNCR	28% - 50%	5 – 12	10 - 20	$1,000 – $2,500
RRI	30% - 35% cyclone boilers	< 1 ppm	4 - 8	$2,500 – $3,000
AEFLGR™	10% - 15%	5 – 12 ppm	10 – 20	$3,000 – $4,000
Hybrid	50% - 85%	< 2 ppm (with catalyst)	> 30 dependent upon configuration	Site Specific > $3,000

Factors Influencing SCR Performance

- Catalyst Quantity
- Flue Gas Temperature
- Stratification of NOx, Velocity, Temperature
- Ammonia Distribution
- Fuel Trace Species
  - SO_2/SO_3 Conversions
  - Catalyst Poisoning (As, P)



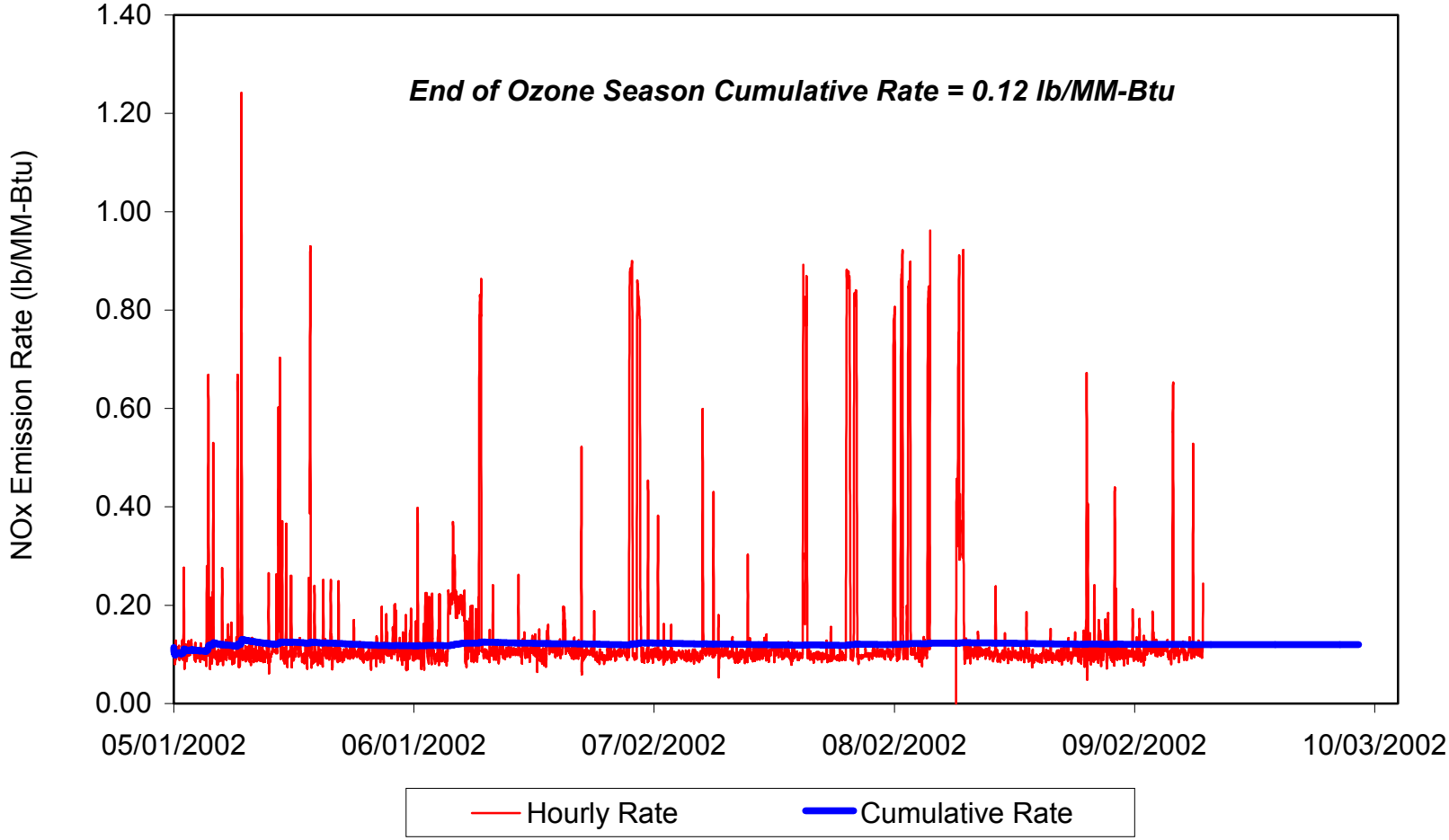
SCR Costs


250
200
150
100
50
0
$ Per KW
0
200
400
600
800
1000
1200
1400
Unit Size (MW)

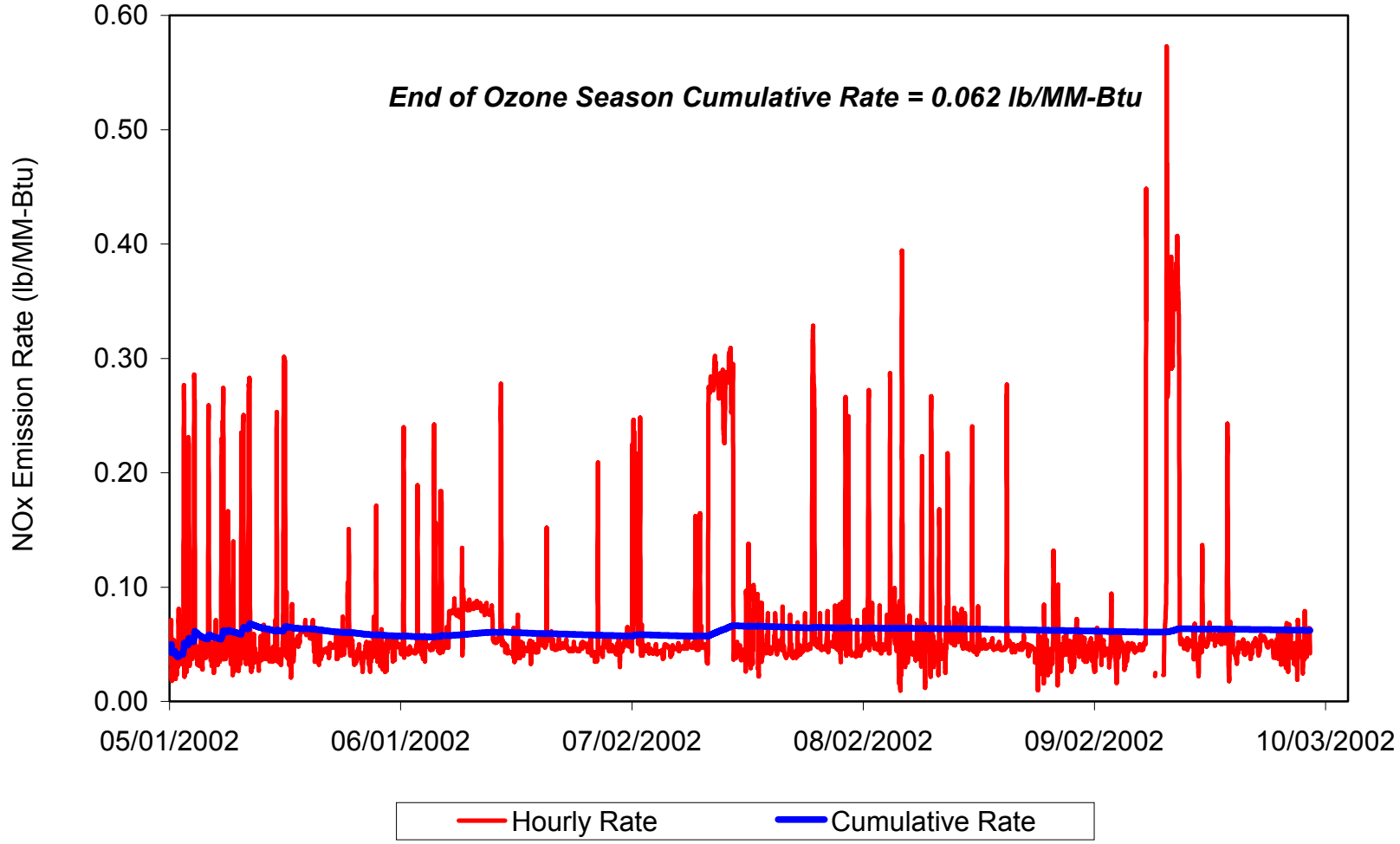
SCR Operating Results – 31 units during 2002 ozone season

- Only ***two-thirds*** of the 31 units maintained NOx rates which averaged below 0.15 lb/MM-Btu for the entire ozone season.
- Only ***one-third*** of the 31 units maintained NOx rates which averaged at or below 0.10 lb/MM-Btu for the entire ozone season.
- The ***two "best"*** operating SCR units appear to have achieved 2002 ozone season average NO_x emission rates of 0.062 lb/MM-Btu.
- N o units could have complied with a 24-hour rolling average of 0.15 lb/MM-Btu

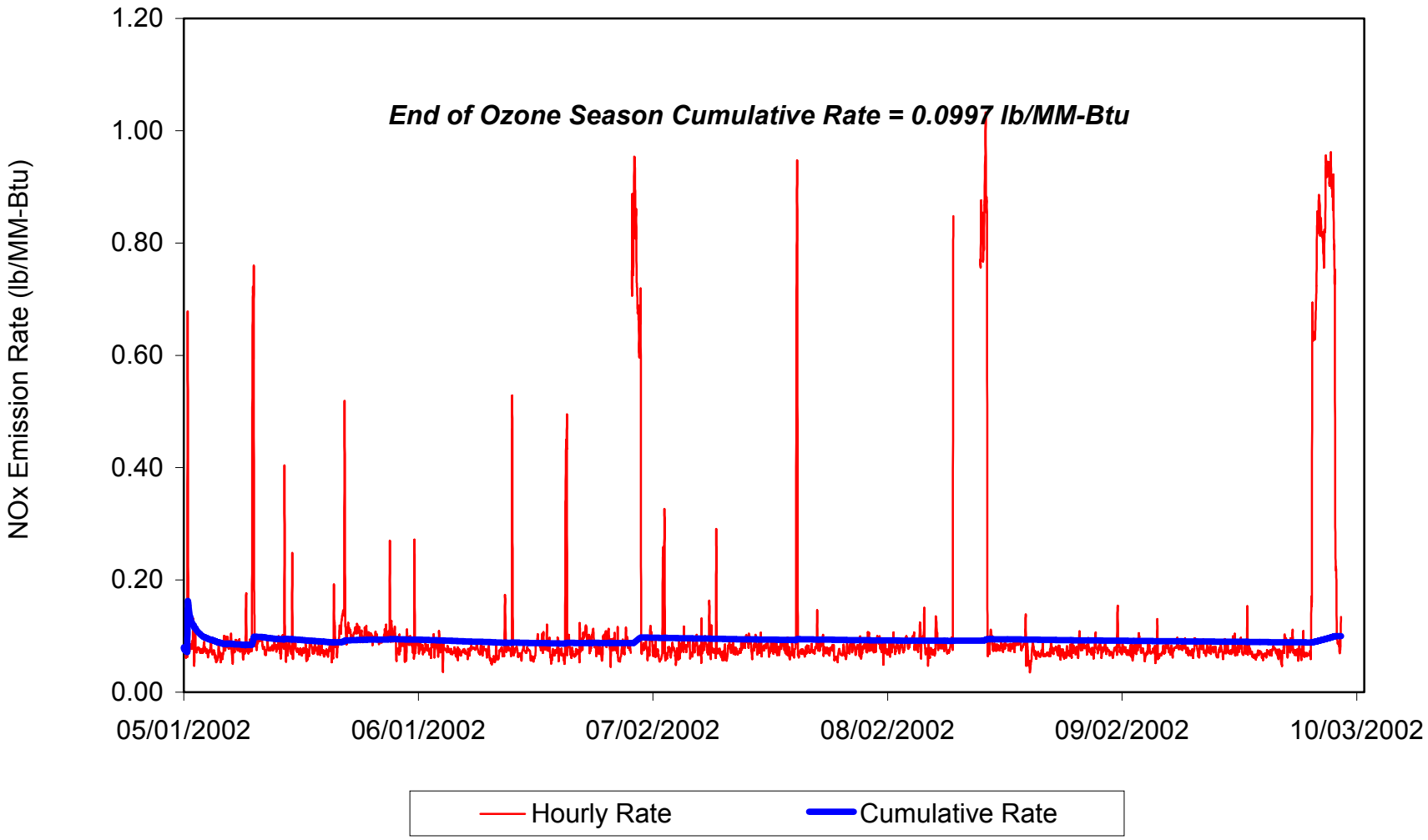
Plant Name: MERRIMACK STATION Unit: 1
Year: 2002 Ozone Season



Plant Name: HL SPURLOCK Unit: 2
Year: 2002 Ozone Season

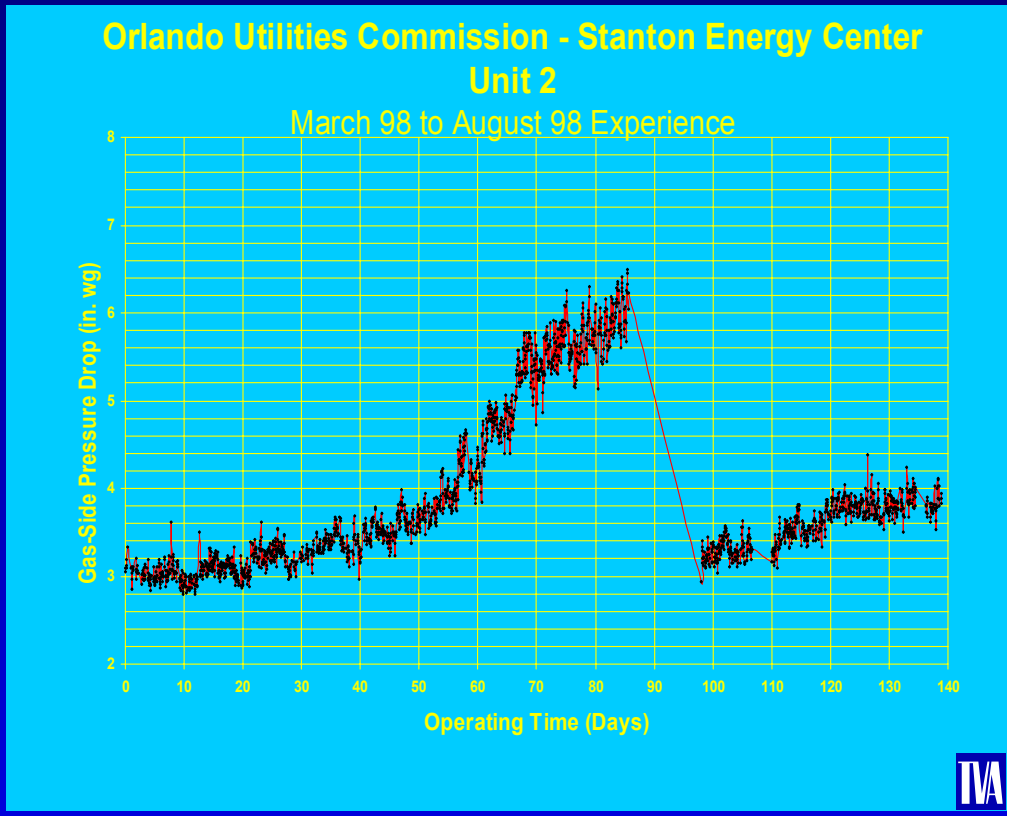


Plant Name: PARADISE Unit: 2
Year: 2002 Ozone Season

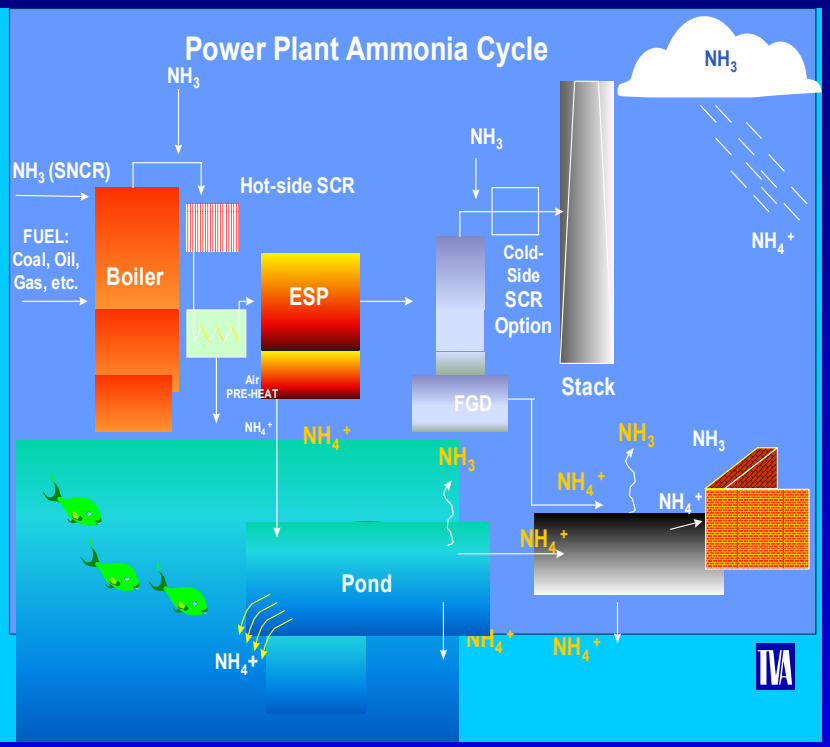


SCR Operational Issues

- Ammonia Slip
- Conversion of SO2 to SO3
  - Air Heater Fouling
  - Ash Contamination
  - Back-End Corrosion
  - Plume Visibility
- Increased System Pressure Drop (4 - 6 i.w.c.)



Other SCR Issues



- Environmental impacts
  - Water toxicity
  - Nitrogen enrichment of waters
  - Visible emissions increase (SO3)
- Manpower availability
- Construction lead times
  - 18-36 months
  - Dependent on site complexity
- Unit outage requirements

Near Commercial Technologies

- Targeting intermediate removal level niches – 50 to 75%
- NOxStar – process demonstrated at TVA Kingston 9
  - Mechanical issues require resolution
- ECO Tube
  - Demonstrated on small units in Europe

Summary

- Low cost utility NOx reductions have been taken
- Advances in combustion modifications will allow small additional reductions
- Post combustion controls on units not controlled through SIP call will be more expensive
- Averaging time for NOx SIP limits should consider operational histories